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IES OCTOBER 1912 NUMBER 22

ALABAMA
GIRLS TECHNICAL INSTITUTE
BULLETIN

NOV 2 1916

1896

Outlines For a Brief Course in Chemistry of Food and Nutrition

Published Quarterly by
Alabama Girls Technical Institute
Montevallo, Alabama

Entered as Second-Class Mail Matter

BULLETIN

OF THE

ALABAMA GIRLS TECHNICAL INSTITUTE

Outlines For a Brief Course in Chemistry of Food and Nutrition.

BY

WILLIAM N. HENDERSON

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Introduction

The purpose of this pamphlet is to present in a simple and direct way the more important of the many facts and principles of Chemistry which are so intimately associated with our lives, our welfare, and our comfort.

This pamphlet consists of a brief discussion of the chemistry of the body, the requirements of the body, the methods of furnishing in an intelligent way these requirements, and a fair outline of the classes of foods and their functions. The experiments, which are made out for each chapter, are, wherever possible, made simple and applicable to domestic use.

In a continuation of this pamphlet a brief discussion of "sanitary chemistry"—which will include the use of chemicals for preserving foods, the application of chemicals for hygienic surroundings, etc.—will be given. This will be accompanied by a short course in the manufacture of domestic articles, such as vinegar, soaps, disinfectants, deodorants, antiseptics, fungicides, insecticides, etc., along with some work in the detection of adulterants and artificial coloring matters in foods.

ACKNOWLEDGMENTS

The author acknowledges no original research work in the preparation of any of the tables and data given in this pamphlet. A liberal use of the following books was made: Human Body, by Martin; Food and Dietetics, by Hutchison; Sanitary Chemistry, by Bailey; Chemistry of Food and Nutrition, by Sherman; and some of the hand books on Domestic Chemistry.

As this pamphlet is merely an outline, the author urges the use of any good authority on this subject.

W. N. H.

May 15, 1912.

CHAPTER I

ELEMENTS AND COMPOUNDS OF THE HUMAN BODY

"Scientists" of ages long since past knew the human body by its mere existance and external physical properties, and were satisfied with their knowledge. As time passed and the power of thought developed, the outward structure of the body presented a complex problem. Distinct parts were recognized, such as head, neck, trunk, and limbs; while these presented smaller parts as ears, eyes, and hands. Even with such an external examination we recognize different materials as teeth, hair, and nails which are components of the larger parts. The hard feel of our finger and the blood issuing from the same broaden our horizon of complexity; while scientists, aided by knives and chemicals, have shown that the body is composed of numerous parts called *organs*, which in turn are built up of a limited number of *tissues*, these same tissues often entering into the make-up of different organs.

It is not our purpose in this brief discussion of the human body to dwell upon the arrangement of the tissues in the various organs or even the location of the latter. That broad subject is treated of in the study of *Histology*.

CHEMICAL COMPOSITION OF THE BODY.—We may go even further in our study of the body and find that the organs and tissues are composed of a number of different chemical compounds which, in turn, are composed of a limited number of elements. Knowledge along this branch of science is far from complete. Analysts, in drawing their conclusions, even after the compounds found in the dead body have been identified, are confronted with the problem as to whether the compounds found by analysis are identical with the compounds as they exist in the living body, or whether they are simpler compounds derived from more complex compounds which have been decomposed in the body since death or during the process of analysis. The body, while alive, is the seat of many constant and complex chemical changes which are inseparably connected with its functions. This field, which offers many problems to be solved, will be left to the study of *Physiological Chemistry*.

The following chapters will be devoted to a brief discussion of the most important classes of compounds of the body, their compositions, their functions, their requirements, and Nature's methods of supplying these requirements.

ELEMENTS OF THE HUMAN BODY.—Of all the elements known only sixteen have been found to take part in the formation of the human body. They are as follows, the non-metallic elements, which are nine in number, coming first:

1. *Oxygen*—A gas; the great supporter of combustion. This gas, which constitutes one-half by weight of the crust of the earth; one-fifth by volume of the air, and eight-ninths the weight of all water, composes two-thirds the weight of the human body, occurring in all tissues mostly in combination with hydrogen as water.

2. *Carbon*—A solid having many forms, the purest of which is the diamond. It is found throughout the body in combination with other elements, and by its oxidation sets free heat and energy.

3. *Hydrogen*—The lightest substance known, is a gas which occurs throughout the body in combination as water, hydrocarbons, and various other forms. When oxidized, it forms water and liberates a great amount of heat.

4. *Nitrogen*—An inert gas, which is an essential part of blood, bone, and all cells—especially those of muscles and nerve organs.

5. *Phosphorus*—A solid, which rapidly oxidizes in the air, occurs in various compounds, in the bones and brain.

6. *Sulfur*—A yellow combustible solid often called brimstone. It is found in all the tissues and secretions of the body, but is always in combination.

7. *Chlorin*—A greenish-yellow corrosive gas which is found chiefly in union with sodium throughout the body.

8. *Fluorin*—A very active gas which is found chiefly in union with calcium in the teeth and bones.

9. *Silicon*—A non-metallic solid occurring in union with oxygen in the hair, bones, blood, and skin.

10. *Calcium*—The metallic basis of lime, and occurs chiefly in the bones and teeth.

11. *Potassium*—A light metal which reacts with water, setting free hydrogen which burns with a lilac flame. It occurs mainly as phosphates and chlorids.

12. *Sodium*—Another light metal which reacts with water similarly to potassium. It is the basis of common salt and soda, and occurs in the body chiefly as a chlorid.

13. *Magnesium*—This metal is found in union with the phosphate radicles, chiefly in bones.

14. *Iron*—This element gives the color to the blood and serves in the areation of the same, aside from being found in various tissues of the body.

15. *Manganese*—A metal, resembling iron in character, is found in traces in the brain and decided traces in the blood.

16. *Copper*—Traces of this metal are invariably found in the brain, and probably in the blood. Lithium and lead have been found, but not in sufficient amounts to be weighed, in blood and muscles.

UNCOMBINED GASES.—Only a few of the above named elements ever occur uncombined. *Oxygen* is found dissolved, or in very loose combination, in the blood. It is found in the recesses of the lungs and in the alimentary canal. *Nitrogen* also exists in the lungs, alimentary canal, and blood. *Hydrogen* is often found free in the alimentary canal, having been set free by fermentation.

CHEMICAL COMPOUNDS.—The number of these existing in the body is very great; but we are unable to state whether some of the compounds found by analysis existed in the body during life in that particular form, since the analyses may have decomposed other complex compounds of which we detect the component parts, or it might be that simpler compounds often unite to build up other compounds. However, we do know the composition of the food as it is consumed, and even when it leaves the body as waste; but science, as yet, has been unable to explain in every case its character during its sojourn in the body.

For our purpose we shall classify the compounds existing in or derived from the body as *organic* and *inorganic*, and the former will be divided into *nitrogenous* or *protein* compounds and *non-nitrogenous* compounds which are *Carbohydrates* and *Fats*. Under the inorganic compounds we have the *mineral salts* and *water*.

CARBOHYDRATES.—This class of compounds is composed of carbon, hydrogen, and oxygen. The hydrogen and oxygen being in the proportion to form water—two atoms of hydrogen to one of oxygen—distinguishes this class of compounds from others composed of the same elements. The more important carbohydrates found in the body are the following:

Glycogen $(C_6H_{10}O_5)n$, sometimes called "animal starch," bears the same relation to animals as does starch to plants. This is a white, amorphous powder, without taste or odor, occurring in all parts of the body and is especially abundant in the liver, where it occurs in the cell structure. The supply of glycogen is increased by rest and liberal consumption of carbohydrate nutrients, but is used rapidly during intensive muscular work.

Tests for Glycogen.—1. This compound apparently dissolves in cold water to a colloidal opalescent solution which is not cleared by filtration, but which loses its opalescence on addition of dilute acetic acid or potassium hydroxide.

2. Iodin added to a water solution of glycogen produces a faint yellow to reddish-brown or red color.

Glucose or grape sugar $(C_6H_{12}O_6)n$ occurs in small quantities in the blood where it is continually undergoing oxidation. When existing in excess in the blood it is stored away as glycogen in the liver, this glycogen being reconverted into glucose in times of need.

Test for Glucose.—1. Glucose when boiled vigorously with Fehling's solution will reduce the cupric salt of the reagent to cuprous oxid which colors the solution red.

Lactose, or Milk Sugar $(C_{12}H_{22}O_{11}.H_2O)n$ is found in considerable quantity in milk. It responds to the Fehling solution test as does glucose.

Inosit ($C_6H_{12}O_6.2H_2O$)n, often classed as a sugar under the name of *muscle-sugar*, but chemically it is not a real sugar or carbohydrate. It is found in muscles, liver, spleen, kidneys, etc.

FATS.—The fats of the body are esters of *glycerol* [$C_3H_5(OH)_3$] and one or more of the fatty acids, of which there are three of much importance, viz.: *Palmitic* ($C_{16}H_{32}O_2$), *Stearic* ($C_{18}H_{36}O_2$), and *Oleic* ($C_{18}H_{34}O_2$). The fats resulting from the union of the alcohol, glycerol, and each of the acids are *Palmatin* ($C_{51}H_{98}O_6$), *Stearin* ($C_{57}H_{110}O_6$), and *Olein* ($C_{57}H_{104}O_6$). At the temperature of the body, the two former are solids, but they are often so mixed with the latter, which is a liquid, as to exist as a mixture of liquid fats.

These fats, whether one or a mixture of more than one, when boiled with a caustic alkali in a water solution, will be decomposed into their corresponding acids and *glycerin.* The fatty acid being set free will unite with the metal of the alkali to form a *soap.*

OTHER ORGANIC NON-NITROGENOUS ACIDS.—The *carbon dioxide* (CO_2) formed by the oxidation of the carbonaceous materials of the body, exists temporarily in the blood and tissues, and while in contact with water exists probably as *carbonic acid* (H_2CO_3). The salts of this acid occur in great quantities in the bones and teeth. *Formic* (H.COOH), *Acetic* (CH_3.COOH), and *Butyric* ($C_4H_8O_2$) acids occur, in addition to the acids already mentioned, in the body. *Phosphoric acid* in combination with *glycerin* occurs in nerve tissue.

PROTEINS.—This class of compounds contains nitrogen and sulfur in addition to carbon, hydrogen, and oxygen. This is the most characteristic class of tissues found in the body, being always closely associated with life. Some one has said that Life and Death centre around the nitrogenous compounds. These tissues have received many characteristic names as *nitrogenous compounds, albuminous bodies,* etc. This class is characterized by the number and complexity of its compounds, the exact formulæ of which are not known definitely. The average composition of the better known proteins of the body is as follows:

Carbon	50 to 55 per cent.
Hydrogen	6.8 to 7.3 per cent.
Oxygen	22.8 to 24.1 per cent.
Nitrogen	15.4 to 18.2 per cent.
Sulfur	0.4 to 5.0 per cent.

Some of the more common forms of proteins are as follows:

Albumin, a very complex compound appearing nearly pure in the white of egg and having the formula $C_{720}H_{1134}O_{248}N_{218}S_5$. This compound is coagulated by heat or dilute mineral acids.

Serum-albumin is found in the blood, from which it may be coagulated by heat. It resembles egg-albumin in character.

Fibrin is formed in the blood when it "clots," either inside or outside the body. It is slowly soluble in saline solutions or strong acids; but is not in dilute acids, alkalis, or water.

Myosin is formed in the muscles after death and renders them rigid or stiff.

Globulin is found united with *hemoglobin*, an iron compound which gives the red color to blood.

Casein exists in milk and may be coagulated by addition of a dilute acid.

Protein compounds respond to the following tests:

1. When boiled with strong nitric acid, a yellow solution is produced which becomes orange when the solution is made alkaline with ammonia. *Xantho-proteic test.*

2. When boiled with the sub- and pernitrate of mercury a pink precipitate or color is produced. *Millon's test.*

PEPTONES.—The true proteins will not dialyze, therefore it is necessary for them to be acted on in such a way as to make them available. These compounds are converted in the alimentary canal into *peptones*, which are soluble and pass readily through the membranes by diffusion.

ENZYMES, OR SOLUBLE FERMENTS.—These substances are very similar to the proteins. Enzymes play a very important role in the drama of "change" throughout the body, but we understand the action of only a few. These indispensable agents are not nutrients in themselves, but serve as catalyzers to change unavailable food principles into food which is readily assimilated by the blood. For instance, *ptyalin* converts starch into sugar; *trypsin* converts albuminous bodies into peptones, and the ferment in drawn blood converts febrinogen into fibrin.

Inorganic Compounds—*Water* occurs in all the tissues of the body to a greater or less extent, composing two-thirds by weight of the average body. A few of the common compounds of the body and their water contents are: Saliva, 99.5 per cent.; blood, 80 per cent.; muscles, 75 per cent., and on down to the enamel of the teeth, which contains only about 2.0 per cent.

Sodium Chlorid—Common Salt—($Na\,Cl$), is found in all the tissues and liquids of the body.

Potassium Chlorid—($K\,Cl$) exists in the bones, blood, nerves, muscles, and most liquids.

Calcium Phosphate [$Ca_3(PO_4)_2$] composes a very large per cent. of the bones and teeth, and is found in small quantities in other tissues.

Beside the above named salts we find the sulfates, phosphates, chlorids, and fluorids, of ammoniam, potassium, calcium, and magnesium. We have also silicon in its various forms principally in the hair, nails, and skin.

Hydrochloric acid ($H\,Cl$) occurs as a constituent of the gastric juice.

CHAPTER II

Food

DEFINITION.—Food may be defined as anything *which, when taken into the body, is capable of either repairing or building tissue, or furnishing heat.*

This definition, though open to criticism as are all others, may be accepted, for it emphasizes the three great functions of foods, viz.: *Constructive*—where the food builds new tissues; *Repairative*—where it repairs the old tissues; *Heat-giving*—where by oxidation in the body potential energy is transformed into heat, part of which in turn is converted into mental or physical work. Though our rule seems to include oxygen, we are compelled to exclude the latter from our list of foods. We note that food, by virtue of the two former functions, provides for the materials of the body, while by the third heat and energy are produced.

Aside from food are substances which may be classed as food adjuncts. Tea, coffee, etc., are, as we shall learn later, members of this group.

In general articles of diet are complex in structure and often contain compounds of no food value; but in most cases the compounds of the food are identical with those found in the body. We should expect this to be so in the case of animal food, and we find it true in vegetable food as well. Elements uncombined rarely being able to nourish the body, we depend upon the compounds for this function.

CLASSIFICATION.—Food may be divided by the following Chemical and Physiological classification:

CLASS I—NUTRIENTS

DIVISION I—INORGANIC COMPOUNDS

Group I. *Water*—This compound comprises about 60 per cent. of the body, being found in great amount in all tissues. It is the carrier of nutritive material and waste products.

Group II. *Mineral Salts*—These compounds serve to build the framework and tissues, to prepare acids and other fluids of the body, and to render other food articles available. For example, we have the chlorids, carbonates, nitrates, phosphates and sulfates, of potassium, calcium, sodium, etc.

DIVISION II—ORGANIC COMPOUNDS

Group III. *Carbohydrates.*—These compounds are known also as "*heat givers,*" for by their oxidation they set free heat and energy. The function of these compounds is to supply the body with heat and energy, though we must say, at this point, that other compounds aid the carbohydrates in this work. This group of nutrients is composed of the three elements, carbon, hydrogen, and oxygen—the hydrogen and oxygen always being in the proportion to form water, i. e., two atoms of hydrogen to one of oxygen.

Group IV. *Fats.*—These compounds also are composed of the three above elements, but not in the same proportion—the oxygen generally occurring in small amount, while the number of hydrogen atoms is large. These compounds are the most concentrated heat producers that we have, the production of heat being their chief function, while when consumed in excess these nutrients are stored away as fat. Examples of fatty compounds are, butter and cotton seed oil.

Group V. *Nitrogenous or Protein Compounds*· This class of nutrients contains, in addition to carbon, hydrogen and oxygen, nitrogen and in most cases sulfur. The proteins are known also as "flesh formers," being the only class of nutrients which, with water and mineral matter, is capable of building up the flesh of the body. Some of the typical protein compounds are, flesh (which contains several of the simple proteins), casein, gluten, etc. These compounds, aside from their chief function of forming flesh, may, by their oxidation, set free heat.

CLASS II—FOOD ADJUNCTS

Group I.—*Alcohol* as contained in wine, beer, etc.

Group II.—*Volatile or essential oils* as we find in ginger, cloves, spices, mustard and pepper.

Group III.—*Acids.* As citric in lemons, malic, tartaric, acetic, etc.

Group IV.—*Alkaloids* as theine in tea, caffein in coffee.

Each group of foods has its chief function while, in some cases, it may have others. The carbohydrates yield heat to the body. This heat serves to maintain the body temperature and to provide the energy for the exertion of muscles or nerves. This nutrient also stores up energy in the form of fat to be dissolved by the blood and used in time of need. Fat is the "concentrated heat producer" which may also give energy and store up fat. The protein is the nitrogenous flesh builder, but is unable to build flesh unless aided by mineral salts and water. This nutrient, aside from this chief function, is capable of undergoing oxidation in the body with the evolution of heat and energy. Water is essential to all tissues and secretions of the body, while the mineral matter aids in the building up and the repairing of the flesh, is the chief constituent of bones, and is necessary for many of the secretions of the body, e. g., the hydrochloric acid of the digestive juices.

The comparison of the body to a steam engine has long been used. We repeat that "the building material of food corresponds to the metal of which the engine is constructed, the energy-producers to the fuel which is used to heat the boilers." But we see that the body is even better than the engine in that the former can draw upon its frame for heat and energy to keep up the vital processes.

The once strong theory of Liebig—that all muscular energy was derived from the proteins and that all heat was derived from only the carbohydrates and fats—has long since been shown to be a mistaken view. Indeed, it is a matter of indifference with the *cell* as to which of the three groups—carbohydrates, fats or proteins,[*] furnishes it with energy; while nearly every cell action carried out in the body liberates heat from the stores of potential energy taken into the body as any nutrient.

We find, however, that the formation of flesh is restricted to the proteins, with water and mineral matter. No one of the three alone can build flesh, nor can any of the foods except the three together.

By our knowledge of the foods and their functions that we have just acquired we may now classify the nutrients as follows:

TISSUE BUILDERS	HEAT AND ENERGY PRODUCERS
Proteins	Proteins.
Mineral matters.	Carbohydrates
Water.	Fats.
	Mineral matters (?)
	Water (?)

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[*] It is a question whether water and salts produce heat and energy.

We notice that protein is the only nutrient capable of performing both functions of foods, therefore its pre-eminence and value in the diet.

The different foods and their functions have now been learned, and by applying the following four tests we may learn their relative value:

1. Chemical.—A determination of the per cent. of nutrients in a food.

2. Physical.—The amount of latent heat stored up in a food which is liberated as energy.

3. Physiological.—The action and digestibility of a food in the stomach and intestines.

4. Economic.—Are the nutrients contained in the food worth the cost?

1. Chemical Test.—By analysis the percentage of nutrients can be determined, and from this an idea as to the value of a food as a heat producer or flesh former is gained.

2. The Physical Test.—This test is to ascertain the fuel value of a food. This value is measured in calories. A calorie is the amount of heat necessary to raise the temperature of one gram of pure water through one degree centigrade. This being an exceedingly small unit, one thousand calories are taken as one *large calorie*—that is, the heat required to raise the temperature of one kilogram of water through one degree centigrade. This test is made by completely oxidizing a certain amount of the food in a *calorimeter* and determining the rise of temperature in degrees C.

It is found that one gram of carbohydrate when oxidized yields 4.1 Cal.; fat=9.3 Cal.; protein=4.1 Cal. Therefore to get the calorific value of a food, for instance milk having 6% carbohydrates, 4% fat, and 2% protein, we multiply each nutrient by its fuel value as follows:

	Per Ct.		Fuel Val.		Total Calorific Value
Carbohydrate	6	×	4.1	=	24.6
Fat	4	×	9.3	=	37.2
Protein	2	×	4.1	=	8.2
Calorific value of 100 grams of milk =					70.0

Fuel value of one pound of some typical foods:*

FOOD	Calories as Protein	Calories as Fat	Calroies as Carbohydrates	Total fuel value per pound
Butter	18	3,559	----	3,577
Peas	418.8	71.7	982.5	1,473
Cheese	553	750	----	1,303
Bread	130	21.5	976.5	1,128
Eggs	232	507	----	739
Beef	391	232	----	623
Potatoes	18.5	9.3	341.2	369
Milk	67	168	87	322
Fish (cod)	299	16	----	315
Apples	9	----	229	238

It is assumed that the whole of each article is edible, and no allowance is made for defective absorption.

3. The Physiological Test.—To know merely the carbohydrate, fat and protein contents of a food and whether it will furnish heat and energy on oxidation is to know little concerning the value of the food. We must know its nature while in the stomach—whether it is easily digested and absorbed into the blood or not.

Many foods rich in one or more of the nutrients escape both digestion and absorption.

Technically speaking, "digestibility" implies that a food is not perfectly absorbed by the blood; but for our purpose—adhering to the common usage—we shall use the word to imply the ease with which the stomach handles and disposes of a food with no sensation of pain or discomfort. While we shall use the word "absorbability" when we refer to the passage of digested food into the blood circulation.

Then a food is *digestible* when it is handled by the stomach in accordance to the above. Food is reduced while in the stomach to a liquid or semi-liquid condition. This task must be performed by the secretions of the stomach before the food is allowed to pass into the intestines, therefore we see that a dense resistant food will remain in the stomach much longer than one which is readily dissolved. Foods of this resistant character are comparatively indigestible. Some foods stimulate the flow of certain secretions, but a discussion of this property will not be taken up in this brief outline.

Some foods have the power of "satisfying" the stomach longer than other foods having a similar composition. This property must not be overlooked in estimating the value of a food from a physiological point of view.

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*Hutchison's Food and Dietetics.

Absorbability

The following is a list of foods and their absorbability:*

	Per Cent. Absorbed			
	Dry Substance	Protein	Fat	Carbohydrates
Meats and fish	95	Practically all	96	—
Eggs	95	“	96	—
Milk	91	88-100	93-98	?
Butter	—	——	98	—
Oleomargarine	—	——	98	—
Fine wheat bread	95.5	81-100	?	99
Meal	93	89	?	97
Rice	96	84	?	99
Beans	82	70	——	?
Carrots	79	61	——	82

1. Absorption of Protein.—We note in the above table that protein suffers a greater loss than any of the other nutrients and that the poorer the food is in protein the greater the loss—as shown by carrots as contrasted with milk.

2. Absorption of Fat.—Fat is absorbed more completely than is protein, but less than is carbohydrate material. There is one great feature which governs the efficiency of absorption of a fat: its melting point. Those fats having a low melting point are readily absorbed as compared with the slow absorption of the more solid ones. For example, the loss of butter by non-absorption is just about one-fourth that of mutton-fat, which has a melting point of 52°C, while the former melts at 37°C. Fat to the extent of six ounces can be absorbed daily by a healthy adult, while increased consumption is accompanied by a very small loss.

3. Absorption of Carbohydrates.—The carbohydrates are the most completely absorbed nutrient that we have. Practically all the sugar consumed by the animal is absorbed by the blood, while only that starch which is in a mass or very indigestible escapes.

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*Hutchison's Food and Dietetics.

Absorbability of a Mixed Diet.—When an animal is fed upon a single diet—e. g., protein—for a while there is danger of having not as complete absorption as if the diet were mixed. This is probably due to the acids and other solvents formed by the mixture of nutrients.

There is a decided disadvantage in the use of foods which are totally—or very nearly so—absorbed while in the stomach and intestines for the intestines need some solid matter—ballast—to stimulate the peristalsis of the intestines. This is found to be especially true in the case of herbivorous animals. Be it known, however, that a large amount of unabsorbed matter also is objectionable. Diets for sick people are often governed by these facts and for details the reader is referred to some good treatise on dietetics.

Food may strikingly be compared to the soil in which a plant grows: Chemical tests can tell the per cents of the plant foods present, but can not tell what per cents will be absorbed. The physiological properties of the plant will have to determine this. So the nutrients of food may be known by chemical analyses, but the value of it is known only by the physiological tests.

4. The Economic Test.—This merely includes a knowledge of the fuel value and of the building material that can be obtained for a certain sum of money. No attempt will be made to go into detail, but that is a very important test for any considerate person. Physicians and dieticians should bear this point in mind when suggesting diets. For a protein diet for a poor man would it be well to recommend chicken when skimmed milk is just as good?

Thus we see that it is hard to determine the value of a food and that it is an ill-formed opinion which is not based on the four above tests.

CHAPTER III

THE AMOUNT OF NUTRIENTS NEEDED IN THE DIET

Since we have learned the nutrients and their functions in the diet, the next question which naturally arises is: How much of each nutrient is necessary in the diet? To this question no definite answer can be made. We have seen that the function of food is two-fold: (1) to build and keep in repair the tissues of the body—or we might say the body itself; (2) to maintain the heat and energy of the body.

It will be the purpose of this pamphlet, not to attempt to answer the question as to the exact nutrient requirement, but to present a few facts which may serve to blaze the trail to a more scientific knowledge of the problem.

We may now enter a brief discussion of the tissue forming and of the heat-producing nutrients and the importance of their quantity in the diet.

PROTEIN REQUIRED PER DAY.—We have seen that the protein compounds command first place in the rank of importance, and we shall not wonder that the question as to the amount necessary in the diet is one of the gravest confronting the students in nutrition today. And until this question is answered, dietetics can never rank as an exact science.

It might seem correct to say that the amount of protein required daily by a person is equal to the protein, or its equivalent, lost as waste from the body daily. For a healthy adult this loss comprises about twenty grams of nitrogen daily and since protein compounds contain about 16 per cent. of nitrogen, we arrive at the conclusion that 125 grams of proteins must be consumed daily. Indeed, this amount is taken as a standard; but this is by no means considered invariable. Should the consumption be more the waste would be more, and vice versa.

It is the tendency for the waste nitrogen to be always equal to the consumed nitrogen and is therefore spoken of as *nitrogenous equilibrium.* This seems at first to be a waste of this valuable nutrient; but on consideration it is found to be quite necessary to supply a liberal amount of protein compounds in the diet. During total abstinence from food, the nitrogen loss is only 4 or 5 grams per day; but experiments where only this amount was administered as food showed that it was *not* enough to establish equilibrium. It is found best to supply three or four times the amount of nitrogen lost during starvation. It is not well to use this small amount of nitrogen, for the protein compounds undergo oxidation to a considerable extent in the body, thereby giving heat and being lost from tissue building. Proteins are the most easily oxidizable of the nutrients and therefore suffer serious loss unless used in connection with plenty of carbohydrates and fats. There are certain compounds like *gelatin* which are known along with carbohydrate and fat as *protein sparers*, i. e., they save the protein from oxidation by being themselves oxidized. The work and nature of the individual have a great influence upon the amount of protein which is necessary. From this brief discussion it is seen that it is a difficult question to answer in an intelligent way. A study of some of the diets used by healthy people will probably give a better answer to this question than will a scientific study of it. It might be added that in most of these standard diets the protein content is about 125 grams. The dietician will have to be guided by the work and nature of the individual as well as by the amount of protein sparers employed in the diet.

HOW MUCH CARBOHYDRATE AND FAT?

When we deal with these two nutrients we know that they can produce only heat; since this can be measured in a very accurate way by two different methods, we are confronted by simply a physical problem to determine the amount of these two nutrients necessary. Not going into details, we may say that the heat given off and the amount of work done by a person may be determined quite accurately by use of a *calorimeter.** The person within does a certain amount of work which is calculated in its equivalent in calories. The calorie equivalent of work added to the heat lost from the body will give the total heat necessary. Then the question is: How shall we supply this heat? We have found that 125 grams of protein are generally used in the diet. This will furnish about 15 per cent. of the total energy required. Now an attempt to supply this remaining heat with carbohydrates only would result in an overloaded stomach and the normal work of the digestive organs would be impaired. Again, fat alone would result in digestive disorders. Aside from these facts carbohydrate material is a more efficient protein sparer than is fat, while fat is supposed by some authorities to take some part in the building of young tissues that the other nutrients can not.

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*See U. S. Bulletin No. 109.

For a man of average build and weight, doing a moderate amount of muscular work, Hutchison has summed up the *standard amounts of the different nutritive constituents required daily thus*:

Protein	125 grams	(4.5 ounces)
Carbohydrate	500 grams	(18 ounces)
Fat	50 grams	(1.8 ounces)

These would yield the following amount of energy in calories:

Protein	125×4.1=	512.5
Carbohydrate	500×4.1=	2050.0
Fat	50×9.3=	465.0
Total		3027.5

Before we draw this brief discussion to a close a few words must be said in behalf of the *Mixed Diet.* That a mixed diet is essential has been demonstrated wherever a person attempted to live on one of the nutrients—or even one kind of food—and water.

No one food contains all the nutrients in proper proportion; being probably too rich in one while probably totally lacking of another. By long experience we have been taught that a mixed diet, properly made out, is man's chief life preserver.

No attempt will be made here to give a standard dietary, and for further information along that line the student is referred to some late authorities on dietetics.

CHAPTER IV

WATER—HYDROGEN MONOXID—H_2O

This is the most abundant compound known. It occurs in every tissue of the body—constituting about sixty per cent. by weight of the latter. Though it is contained in every morsel swallowed, it must be consumed with dry matter in about the ratio of three pounds of water to one of the former.

FUNCTIONS.—The importance of water can not be over-estimated. It is one of the most important of the food materials. In the plant, water is used in the manufacture of food, uniting chemically with other materials. Though water is found free in all tissues of the body, it is not a settled question as to whether any of the elements of these tissues were furnished by the water, for the food always contains plenty of hydrogen and oxygen. The most important use of water in connection with the food is to serve as a carrier of the food over the body. The solvent and carrying powers of water make it of excellent use in this latter function. And if we can not say that water enters into the composition of the various tissues, we can say that it serves as a medium in which chemical, physical, and physiological changes take place.

WATER FROM A SANITARY POINT OF VIEW.—Water is impure when it contains any material other than hydrogen and oxygen combined as H_2O. All impurities need not necessarily be injurious. Indeed, many impurities give excellent drinking qualities to water and are often recommended by physicians. The objectionable impurities may be in the form of either: (1) excessive saline material; (2) organic matter, either animal or vegetable, decaying, facilitating objectionable chemical changes, and serving as food for bacteria; (3) bacteria. The amounts of these impurities vary in regard to the soil through which the water flows, the water of course assuming the character of the soil through which it flows. Impurities in water aside from being beneficial or harmful are either mineral or organic.

THE MINERAL IMPURITIES in water are generally the chlorids, sulfates, carbonates, and nitrates, of potassium, calcium, sodium, magnesium, and some iron salts. Water containing potassium or especially sodium salts in excess is spoken of as alkali water, and such water often causes digestion disorders, when consumed, by acting upon and irritating the mucous membrane of the digestive tract. The so-called *Mineral Waters* contain an abnormal amount of some common salt or a small amount of some rare mineral. These waters often contain minerals of medicinal value and are often used for this property. Before the use of such waters it is well to consult a good physician. Baleful results have often been encountered while seeking relief in the wrong kind of mineral waters.

HARD WATER.—Temporary hardness. Pure water will not dissolve calcium carbonate, but water containing carbon dioxid in solution readily dissolves the salt, forming calcium acid carbonate. Water flowing through a limestone country will always incorporate this gas which enables the water to dissolve the mineral. Water containing the bi-carbonate of calcium is temporarily hard water, for, on boiling, the carbon dioxid is expelled and the carbonate being no longer soluble separates out. Thus the water is rendered soft.

Permanently hard water contains the chlorids and sulfates of calcium and magnesium. Such water is not softened by boiling or any other simple treatment; but the water may be rendered less hard by one of several different methods which involves chemical changes.

Though the hardness of water is of little consequence in water for potable purposes only, it is very important where the water is to be used for cleansing purposes—the minerals rendering the water hard will react with the soap, forming an insoluble compound and thereby causing great loss of the soap. Where calcium bi-carbonate is the only hardening agent in the water, the latter may be rendered soft by boiling; where the salts causing permanent hardness are present, the hardness may be decreased by the addition to the water of such salts as borax or sodium carbonate. It is often desirable to determine the hardness of water. This is done by determining the amount of pure soap necessary to form a lather which persists for five minutes in the water.* Water containing much mineral matter is purified well only by distillation.

ORGANIC MATTER IN WATER.—From a sanitary point of view the organic content of water—which is often unnoticed by any of the senses—is of the greatest importance. We have seen that water dissolves much of the mineral matter over which it flows. In its course through or over the soil, water often comes in contact with decaying animal or vegetable matters which may be dissolved or carried along in suspension by the water. This organic matter may contain nitrogenous compounds which are in themselves unwholesome or even poisonous, or the compounds may serve as food for undesirable bacteria. The old saying that "water purifies itself every hundred yards" may be changed to "water contaminates itself every hundred yards." When exposed to the air or oxygen, these impurities are undergoing oxidation—(hence the old saying)—caused by the oxygen through the agency of the bacteria. Organic matter does not remain in one form very long under these conditions. The nitrogenous compounds are split up into ammonia which is readily converted into nitrous acid, which gives rise to its salts, the nitrites, which in turn are oxidized by another set of bacteria to nitrates. The ammonia, nitrites, and nitrates are not in themselves harmful, but they throw out the danger sign of contamination by nitrogenous organic matter which should be avoided. Water containing this material serves as an excellent medium for bacterial growth, and the bacterial content of water is by far the most important feature determining the potableness of the latter. The amount and character of organic matter may be determined by evaporating the water to dryness over a gentle heat and observing the residue. If the residue is black organic impurities are present, while on slow oxidation of the residue nitrogenous compounds will give off an odor of burning hair or feathers.

EXPLANATION OF A WATER ANALYSIS.—Where a water is evaporated to dryness at 100°C the residue, which consists of the mineral, animal, and vegetable matter, is called "the total solids." The first stage in the decay of organic matter liberates ammonia which, before it is acted upon by bacteria, is called the "free ammonia." This is necessarily very small, as the ammonia is attacked soon after liberation. Before complete oxidation has taken place we have ammonia in the form of "albuminoid ammonia." Nitrates being the end of the oxidation of nitrogenous compounds are not so objectionable in water as are the nitrites, which are very closely associated with the original compounds, thereby indicating "recent contamination." Chlorin in large amounts indicates either excess mineral chlorides or sewage contamination.

Before leaving this point, it might be well to say a few words in regard to the bacteria which are water-born. The bacilli of typhoid, dyptheria, small pox, measles and many other diseases are distributed by the water supply. Epidemics which destroyed thousands of human lives have been traced to the unsanitary act of some individual.

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*See laboratory exercises, Exp. on hardness of water.

METHODS OF IMPROVING WATERS.—Waters may be improved by any or all of the following ways: (1) Boiling, which, when carried out properly, consists in boiling the water vigorously for at least ten minutes, then cooling out of contact with dust or any form of contamination; (2) filtration, which is often rendered very effective by addition of a coagulent such as aluminium hydroxid, or ferric hydroxid. This process removes all the suspended particles; (3) distillation separates the water from all forms of impurities and kills the bacteria; (4) chemical purification, which often kills germs, oxidizes organic matter, and often facilitates filtration; (5) by freezing, which kills many of the organisms and reduces the vitality of the others.

VALUE OF SANITARY WATER.—Pure water is probably the greatest promoter of the people's health. The cost of sanitary water is not to be compared with the cost of human life. Though no water on the earth's surface is pure, we should strive to use water containing only harmless or beneficial impurities. It will be well to mention at this point the *lead poisoning* which so often proves fatal. This is caused by use of water containing the soluble salts of lead which may—but rarely—occur naturally in the water, but which more often come from the lead pipes. Water containing salts and acids will convert the lead into a poisonous salt which, if soluble, will be consumed and will often cause death. Where lead pipes are used to conduct the water to the house, it is well to allow the water, which has stood in the pipe for any considerable time, to run off before the water for drinking purposes is obtained. Neglect of this has caused in many cases fatal results.

With the poisonous salts and organic compounds in the earth, the poisonous salts of the pipes, and the ever-present bacteria in the soil and air, we are faced on all sides by problems for pure water. Little we who obtain our waters from the clear, cool, clean springs have to concern us of our own welfare; but may the rapid strides of science soon place a cheap and sanitary fountain of this all-important liquid in every home.

CHAPTER V

Mineral Matter in Foods

The question whether mineral matter is an important food is answered in the affirmative by the analysis of the body which shows that the latter contains about five per cent. of ash, about eighty per cent of this total being found in the bones.

These inorganic elements take part in the functions of the body in at least four different ways: (1) they give strength, permanence, and rigidity to the tissues; (2) they are essential elements of the protoplasm; (3) their solutions give energy to the body and serve to sensitize the nerves; (4) and to render acid and alkaline the fluids of the body.

The list of elements comprising the mineral matter of the body may be narrowed down to sodium, potassium, calcium, magnesium, and iron as the metallic elements, and phosphorus, chlorin, sulfur, and small amounts of silicon and fluorin, which represent the non-metals.

Granting that these constituents are necessary as tissue builders—indeed it has been shown by experiments that death follows a few weeks' total abstinence from mineral matters even where all other foods are consumed in normal amounts—the question as to the value of these nutrients as a source of heat and energy naturally confronts us.

The fact that the mineral matter is already highly oxidized when it enters the body answers in the negative the former. But the salts in solution possess properties, aside from their chemical properties, that make the constituents of value in the body. Though these substances are unable to produce heat by their oxidation in the body—as are the proteins, carbohydrates and fat—they are capable of giving energy to the body by virtue of their osmotic properties. Even dilute solutions of these salts often exhibit an osmotic pressure of from five to ten atmospheres.

When it is known that the fluids of the body have an osmotic pressure of six atmospheres, it is readily seen that the consumption of these mineral solutions increases in a marked degree the total osmotic pressure in the body, thus giving energy to the same. We now see that the mineral matter acts not only as a tissue builder, but also as a source of energy as well.

Science has not advanced to the point where it can make known the *mineral requirements* of the body. But this point may be of little consequence so long as the usual mixed diet is consumed, for it contains even more of the mineral salts than are necessary. The body is not indifferent as to the *form of salts* it is supplied with, i. e., whether these salts are in an inorganic or an organic condition. Indeed, it has been found that when salts are given only in the form of inorganic compounds to the body that life is not sustained; but often inorganic medicinal preparations are administered along with the mixed diet with desirable results. However, it might be said that nearly all of the mineral matter used by the body is supplied through organic compounds. We shall now take up a brief outline of the principal mineral substances of the body and incidentally mention a common source of the nutrient under discussion.

CALCIUM.—Calcium is found chiefly in bones, the latter containing 99% of the total calcium phosphate found in the body. This salt constitutes three-fourths of the mineral matter found in the bones. Calcium salts are readily absorbed by the body, but are given off during metabolism to such an extent that it has been generally believed that these salts escape absorption during their sojourn in the body. It has been estimated that about .7 per cent. of calcium oxid is required by an average man. This being the case, the "family diet" should contain sufficient calcium to supply the needs of young people. A young child requires a larger quantity of calcium than does a man. The bones of the growing child demand a liberal supply of this element, and if this amount is not supplied defective bones and even disease of the latter will result. Nature has provided for this requirement of the young by placing a large amount of calcium in milk. Where this food is not used, other compounds of calcium must be used to supply the necessary element. It has been found that the extensive use of food deficient in calcium will result—even with adults—in defective bones. The reason for this is explained by the fact that the formation and preservation of the flesh require calcium and if this requirement is not satisfied by the food the bones are drawn on for their calcium. This removal of calcium from the bones often results in soft, diseased, and even perforated bones.

Calcium is found in the fluids of the body, where it plays its part in producing energy and rendering irritating and alkaline these important factors of the human machine.

It may be mentioned that milk, eggs, cereals and nuts are rich in calcium and are excellent mediums through which to supply this element.

MAGNESIUM is found in the body in less quantity than is calcium, although it occurs in food in just about the same proportion as the latter element. Though magnesium and calcium are very similar in most of their properties, it is known that they are even antagonistic in some of their functions in the body: for example, magnesium salts alone cause inhibitory effects upon the muscles of the body, while calcium has just the opposite effect. Continued pulsation of a dissected heart may be effected for some time by bathing the heart muscles with a solution of calcium (which causes contraction) and magnesium (which causes relaxation) salts. Magnesium is found in combination in the bones and other tissues of the body, but in small amounts. This element is present in milk, bread, meats, and many other of the common foods in sufficient quantity to supply the needs of the body.

IRON.—It has been estimated that about ten milligrams of iron are used per day in an ordinary mixed diet. It is an easy matter to keep the iron content of the blood to its normal amount, but once this amount is too low it is of little use to attempt to supply the deficiency by increased iron content of the diet. An accurate iron content of the foods can not always be given in general terms, for it has been found that plants grown on ground poor in iron are themselves poor in this element, while animals which have been bled are correspondingly poor in iron. This element is distributed throughout the body, occurring in large proportions in the bones and blood, giving the red color and serving in the areation of that fluid.

SODIUM AND POTASSIUM.—The irritating actions of the fluids of the body are due largely to the sodium content. This element is essential to the fluids. Potassium turns its work to the building up of the cells, especially the cells of the muscles. It has been shown that young animals develop weak and inferior muscles when fed on a diet containing little or no potassium. Scurvy is often accompanied by the diminished alkalinity of food (which will be explained in a separate paragraph) and it is known that potassium acts as a base-forming element; thus its importance, along with others of its class, in preventing such conditions.

Most of the sodium is supplied as sodium chlorid. The average person consumes far more of this compound than is needed to supply the element; but it seems that naught but good can be said about over-consumption of this salt. It serves to produce the hydrochloric acid of the digestive fluids. Plenty of salt is supplied by meats; but it is often necessarily added to vegetable diets.

PHOSPHORUS.—This element is essential for the cell nuclei, in all nerves, and in the bones. It may be said that phosphorus must be present where growth is taking place. It might, however, be said for phosphorus as well as all other mineral ingredients (with the exception of iron, potassium and calcium) that no disease can be traced to its deficiency in the diet. We have seen that a deficiency of calcium results in the softening of the bones, while the lack of iron may result in anaemia, and insufficient potassium causes inferior muscles and disease.

CHLORIN is important, inasmuch as it forms the hydrochloric acid of the body. It is taken in the forms of sodium chlorid into the body.

FLUORIN occurs in combination with calcium in the teeth and to a smaller degree in the bones.

SILICON is found in the hair, skin and nails. These last two elements are supplied mostly by the cereals.

CHARACTER OF ASH CONSTITUENTS OF FOOD.—The acidity and the alkalinity of diets should not be overlooked, for on each of these properties depend changes important to the human welfare. Acidity to a certain extent is very important in the digestion of the food, but alkalinity is equally important for the prevention of acidosis. Chlorin, phosphorus, and sulfur are the three important acid-forming elements, while sodium, potassium, calcium and magnesium are the leading base-forming elements. It is considered, by some people, necessary to have in the food sufficient of the base-forming elements to neutralize the acid of the other elements so as to prevent the disease of scurvy.

Some of the common foods in which acid-forming elements predominate are: Bacon, eggs, rice, meal, flour, beef, etc. While the following exhibit alkalescence during metabolism: Milk, fruit,* and vegetables.

cause the original acid is a weak acid potassium salt, which on oxidation yields the free alkaline ash.

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*Even the strongly acid fruits yield an alkaline ash on oxidation, be-

CHAPTER VI

Carbohydrates

The compounds of this class are composed of the three elements carbon, hydrogen, and oxygen, the general formula being CH2nOn. Among the members of this class of nutrients may be mentioned the sugars and the starches along with cellulose—which, however, is considered by some authorities as not being a true carbohydrate.

The carbohydrates, as has been mentioned before, are often spoken of as "heat-producers," this being their chief function in the body. Aside from giving heat by their own oxidation in the body, they serve as protein sparers, being themselves oxidized instead of the latter. When this element of nutrition is consumed in excess the surplus is stored up in the form of fat, which is an exceedingly concentrated form of energy. This fat is dissolved for use by the blood in time of need.

The carbohydrates are by far the most abundant constituents of a vegetable diet, but are found in less proportion in the meats. This class of nutrients, as a whole, is easily digested and absorbed and the most economical of any of the foods.

In the internal laboratories of the leaf the chlorophyll makes use of the sunlight in synthesizing this nutrient from the water of the soil and carbon dioxid of the atmosphere. These reactions are not wholly understood as yet, but the latest works along this line go to show that the water and carbon dioxid, under the influence of chlorophyll and sunlight, undergo reactions giving rise to formaldehyde and oxygen. The oxygen escapes while the former is polymerized into sugar, which in turn loses water and is left as starch or cellulose:

$$CO_2+H_2O=H.CHO+O_2$$
$$6H.CHO=C_6H_{12}O_6$$
$$C_6H_{12}O_6=H_2O+C_6H_{10}O_5$$

In many grains, roots, tubers, etc., this organic compound is in the form of starch; while in the body, etc., of plants it is in the form of cellulose.

There are three important classes of the carbohydrates and in each class may be found three important members:

(1) Monosaccharides ($C_6H_{12}O_6$).—Under this division we have the simple sugars—those which can not be split by hydrolysis into sugars of lower molecular weight:

Glucose (dextrose, grape sugar, starch sugar) occurs widely distributed in nature in plants and fruits, and is found to the extent of 0.1 per cent. in healthy blood. This form of carbohydrate is readily taken up by the animal, the blood absorbing it, then giving it up for oxidation. Glucose readily undergoes fermentation with yeast, giving rise to ethyl alcohol and carbon dioxid as follows:

$C_6H_{12}O_6=2C_2H_5OH+2CO_2$.

Fructose (fruit sugar, levulose) is found along with glucose, and is found in large amounts in the nectar of flowers.

It has been found that under favorable conditions fructose may be changed into glucose and *vice versa.* Fructose is not readily taken up by the blood and is, on reaching the liver, converted into glycogen $(C_6H_{10}O_5)n$ by loss of water, but is by hydrolysis converted into glucose:

$C_6H_{10}O_5+H_2O=C_6H_{12}O_6$.

Galactose is formed by hydrolysis from milk sugar by either acid or enzyme, and has the power of producing glycogen in the body. Galactose is not found free in nature.

DISACCHARIDES

The members of this group have the common formula $C_{12}H_{22}O_{11}$ and are important articles of food, being converted during digestion into the monosaccharides.

Sucrose (cane sugar or saccharose) occurs in the juices of many plants, especially in the sugar beet, sugar cane, and maple. Glucose and fructose are the results of hydrolysis of sucrose. The synonyms for glucose and fructose are "dextrose" and "levulose." The former rotates the plane of polarized light to the right, the latter to the left. "Inversion" is the name applied to the hydrolysis of cane sugar, and the glucose and fructose formed are known as "invert sugars." Sucrose is a readily available foodstuff.

Lactose (milk sugar) is found to the extent of 4 to 7 per cent. in the fresh milk of animals. Glucose and galactose are formed by the acid or lactose (intestinal ferment) fermentation of lactose. This hydrolysis is seemingly necessary for the absorption of the original compound.

Maltose (malt sugar) is produced from starch, during the germination of a grain, by the diastatic enzymes (amylases). The hydrolysis of starch by means of a mineral acid forms maltose as an intermediate product.

POLYSACCHARIDES

These compounds differ from the preceding compounds by being uncrystallizable, non-diffusible, and insoluble in alcohol. Starch and glycogen of this group are very important in that they are the forms in which carbohydrates are stored in plants and animals.

Starch $(C_6H_{10}O_5)n$ is found in granules widely distributed throughout the vegetable kingdom. It is found extensively in grains like corn and tubers like potatoes, and is often spoken of as corn or potato starch. Starch is insoluble in cold water, but when heated in the latter it swells and bursts, forming a solution which on cooling gives the familiar starch paste. Starch undergoes hydrolysis when in contact with a dilute mineral acid, saliva, or some of the digestive ferments. The test for starch is the blue color produced in a cold iodin solution.

Dextrin $(C_6H_{10}O_5)$ is formed from starch by the action of either acids, heat, or enzymes. When the starch of a germinating grain is acted on by malt diastase small quantities of dextrin are produced along with the maltose.

Glycogen $(C_6H_{10}O_5)n$, or animal starch, as it is often called, fills the same position in animals as starch does in plants. This is a white, amorphous powder which apparently dissolves in cold water. This compound is found in all animals in all parts of the body, acting as stored-up fuel which is dissolved by the blood and used to produce heat and energy in time of need. This carbohydrate often accumulates in the liver, especially during excess consumption and rest.

CHAPTER VII

Fats

It has been said by one writer that a quart of alcohol is manufactured and used daily in the body. What is this alcohol? one may ask, and what becomes of it? Some of this alcohol we can say is glycerol—$C_3H_5(OH)_3$—and that it is neutralized by the free fatty acids of the body to form neutral compounds called esters. These esters are glycerides—glycerol esters of fatty acids—or fats. These fats may be in the liquid or solid state. When in the former, they are oils, when in the latter, fats. Since the alcohol is triatomic and the fatty acid, or stearic acid, to use one acid, is monatomic, the equation will be:

$$\underset{\text{Glycerol}}{C_3H_5(OH)_3}+\underset{\text{Stearic acid}}{3C_{18}H_{36}O_2}=3H_2O+\underset{\text{Stearin}}{C_3H_5(C_{18}H_{35}O_2)_3}.$$

The reverse reaction where some alkali is used to saponify the fat is carried out in the manufacture of soap—producing an alkali salt of the acid and forming the glycerin. This process is called saponification. Hydrolysis implies the decomposition of any organic salt, or ester, into its alcohol and acid. This might be done by steam under pressure and if the fat is glycerol tri-stearate the products of hydrolysis will be glycerol and stearic acid (the reverse reaction given above). Where an alkali, e. g., NaOH, is used we have the sodium replacing the one atom of hydrogen in the acid and a soap produced:

$$\underset{\substack{\text{Glycerol tristearate}\\ \text{stearin}}}{C_3H_5(C_{18}H_{35}O_2)_3}+3NaOH=\underset{\text{Glycerol}}{C_3H_5(OH)_3}+\underset{\text{Sodium stearate}}{3C_{18}H_{35}O_2.Na}.$$

The fats constitute a definite group of chemical compounds, consisting of only the three elements carbon, hydrogen, and oxygen. All fats are insoluble in water, but are dissolved by the solvents like ether, benzene, chloroform, and carbon bisulfid. A pure fat is colorless, tasteless, and odorless; the three reverse properties of an impure fat being due to the impurities. Butter is one exception. There are several series of fatty acids, each series having a common formula. Probably the most important group has the common formula $CnH2nO_2$. A few of the members of this group are:

Butyric acid ($C_4H_8O_2$) occurs in butter to the extent of 5 or 6 per cent.

Palmitic acid ($C_{16}H_{32}O_2$) occurs in many fats both animal and vegetable; also in some waxes as beeswax.

Stearic acid ($C_{18}H_{36}O_2$) occurs in large quantities in many fats having high melting points.

A second series of acids has the formula $CnH2n\text{-}2O_2$. This group is characterized by containing only unsaturated compounds of low melting points. In this group we have oleic acid ($C_{18}H_{34}O_2$), which is found as a glyceride in nearly all fats and oils. Lard, olive oil, etc., consist mainly of olein.

There are many other fatty acids, each producing its characteristic fat.

FUNCTIONS OF THE FATS.—The chief function of the fats of food is to give heat and energy to the body. They are the most concentrated of the heat producers, and although they are harder to oxidize in the body than are the carbohydrates, the fats serve as immediate sources of heat. When all the fat is not used in the immediate production of heat in the body, the excess is stored up in the form of fat, which is dissolved by the blood in time of need. This stored up fat is the most concentrated fuel that the body has.

CHAPTER VIII

Proteins

The proteins are very complex and usually amorphous compounds differing widely in composition and properties. The chemical structures of these molecules of high weight are very incompletely known. Taken as a whole the proteins contain about 52 per cent. of carbon, 6 to 7 per cent. of hydrogen, 22 per cent. of oxygen, 16 per cent. of nitrogen, and less than 2 per cent. of sulfur; these compounds always containing carbon, hydrogen, oxygen, nitrogen, and often sulfur, iron, phosphorus, etc. These elements are contained in many radicles, which are very often complex, combining to form the molecule.

The proteins are often called "flesh formers," "muscle builders," and "nitrogenous compounds"—this indicated element characterizing the class of compounds. These compounds are closely associated with the life processes, being the chief constituent of plant and animal protoplasm. Proteins differ widely in their solubility in alcohol, water, and salt solution; but are all insoluble in the common solvents like ether, benzene, carbon bisulfid, chloroform, etc.

There are many classes of proteins and many members of each class, but only a few of the more important ones can be mentioned here.

Albumins and *globulins* are associated in blood serum and cell substance. Generally speaking, the albumins occur in greater amounts in the fluids (blood, etc.) of the animal body; while in animal tissues and plants the globulins predominate. There is little difference between these two proteins, globulins being insoluble in pure water while albumins are soluble.

Alcohol-soluble proteins and *glutelins* are found in cereal grains. Gliadin and glutenin of wheat flour are the most familiar ones. Approximately 40 per cent. of the total protein in flour is glutenin and about 50 per cent. is gliadin. The gluten of wheat flour is composed of these two protein compounds. The "cooking properties," elasticity, strength, etc., of gluten depends upon the proportion of these compounds: two parts of gliadin to one of glutenin favors good cooking qualities in bread.

Albuminoids have often been disqualified as being true proteins on account of gelatin (a typical albuminoid) which will not support the protein metabolism* of the body. This having been found true for other typical proteins, the albuminoids are reinstated as true proteins.

Nucleoproteins—compounds of simple proteins and nucleic acid—are found as essential proteins in the cell nuclei. These compounds are rich in phosphorus.

Phosphoproteins, as their name implies, are rich in phosphorus, holding this element in a much more stable form than the preceding class of proteins. We find numbers of this class as casein of milk and vitellin of egg-yolk.

Hemoglobin as found in blood is a protein compound containing iron. This compound serves to areate the body by carrying the oxygen from the lungs to the tissues.

There are many other proteins, but the above serve as typical examples of the class.

The term *Crude Protein* is often used to denote the "total nitrogenous compounds"—some of which are far from being proteins. In a chemical analysis of a food the nitrogen content is determined and this is multiplied by 6.25 in order to get the amount of protein in the food. It has been said that nearly all protein compounds contain about 16 per cent. of nitrogen, so it is readily seen that multiplying the nitrogen content by 6.25 will give the protein equivalent.

FOOD VALUE OF PROTEINS.—The proteins have more functions in the body than any other nutrient. This is probably due to the complexity of the molecule. The chief function of the proteins is to build tissue—either to form new tissue in the process of growth or to repair worn out or destroyed tissue. Proteins alone, however, can not build permanent tissue. Mineral salts and water are necessary to help in this important function. Aside from building tissue the proteins produce heat by their ready oxidation, and even store up fat when conditions favor its production. It is not desirable to consume so much protein that it is left without a function in the body—or even to be oxidized—for, first, protein is the most expensive article of diet; second, disease often accompanies over-consumption.

OTHER NITROGENOUS COMPOUNDS

AMIDS AND AMINES are compounds derived from ammonia by replacing one of the atoms of hydrogen by an organic radicle. They are of simpler structure than the proteins. Amids are formed in plants during the production of protein compounds, while in the animals amids are produced during oxidation and digestion of the proteins.

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*Chemistry of Food and Nutrition.—Sherman.

ALKALOIDS.—This class of compounds is common to many of the plants—especially the plants used for medicinal purposes. These compounds like ammonia, morphine, quinine, etc., have no food value, but are useful for their medicinal effects. Though common to many of the non-edible plants alkaloids are produced in flesh only when the latter ferments. These compounds when produced in meats are known as ptomaines.

RELATIONSHIP OF FOODS—Nitrogenous and Non-Nitrogenous.—We have seen that the invert sugars—e. g., glucose and fructose—may be derived from sucrose by hydrolysis, so may amids and alkaloids be formed from protein. The two invert sugars can not be made to reform the original cane sugar, neither may the protein be reformed by any laboratory means at the hand of man from the components—amids and alkaloids.

The plants absorb the nitrogen as soluble salts and build it first into amids and then into proteins. These plants may be consumed by an animal; the protein of the plant now undergoes oxidation and decomposition into amids which are eliminated from the body. These amids undergo oxidation and nitrification and are soon converted into nitrites and finally into nitrates which the plants may take up again. Thus the nitrogen cycle is repeated just as the oxygen in respiration. Nature in all her earthly richness is mindful of even a little atom of nitrogen and saves it against a day of need.

CHAPTER IX

Effects of Cooking Food

There are two good reasons for cooking food: First is *aesthetic*—that is to make it more appetizing by improving the appearance or flavor, or both. Second, is *hygienic*—that is to destroy by heat any undesirable or dangerous organisms that the food might contain. The belief that cooking increases the digestibility of food is true only in the case of vegetable foods. The digestibility of animal foods is actually decreased. This statement is made, however, from a *chemical* point of view. It is known that the tempting appearance or flavor of a food increases the flow of saliva and digestive juices, thereby adding to the ease of digestion; therefore a food cooked so as to present these pleasing properties receives a better and quicker response from the digestive organs, but these organs, however, must go to a greater expenditure of work, in the case of many animal foods, on account of the compounds in these foods having been rendered less digestible.

The *protein* compounds are coagulated at 76°C and any heat used in producing a higher temperature is wasted. An oversight of this fact often leads to excess cooking, which renders the proteins hard and less digestible.

On the different *carbohydrates* heat has a slightly different action: Starch is converted by dry heat into dextrin, which is more easily digested and has a sweet taste—this reaction is produced to some extent in the crust of bread during cooking. Moist steam causes the starch granules to rupture and form a gelatinous mass. The latter change is caused by a temperature below that of boiling water.

Sugar is converted by heat into a brown substance called caramel. This compound, left when sugar gives off water, produces flavor in the food.

Fats are not readily decomposed by heat; but when a high temperature is reached the fat dissociates into free fatty acid and glycerine. This might explain the irritating action of hot fat. On cooling, however, the acid reunites with the glycerine to form the fat.

THE COOKING OF MEAT

We have learned that cooking animal food does not render it more digestible. The first object of cooking meat is to remove the bloody color—thereby giving it a more pleasing appearance—and to do this in such a way as to retain all the flavoring materials.

BOILING is not a good name for the process of cooking meat in water for the reason that the hemoglobin is decomposed into a brown compound before the boiling point of water is reached. Above this temperature the protein compounds will become hard. Then boiling meat should not go above the temperature necessary to coagulate the protein—this temperature being sufficient to destroy the bloody color.

A second object in boiling meat is to retain all the flavor. This flavor is due to extractives and salts—both of which are soluble in water. Therefore in boiling meat just as little water should be used as possible; in fact, just enough to completely cover the meat. This is readily seen when we think that the more water we add to the meat the more soluble matter will be removed. These flavoring materials being soluble are removed in proportion to the water added. Where soup is made the extractives and salts should be in the solution, and in this case the loss from the meat is not objectionable.

There are two methods of preventing this loss—or excessive loss—of flavor from the meat. The first is to use very little water. The second is to dip the cold meat into boiling water and allow it to stay there a few minutes. This coagulates and hardens the thin outer layer of proteins, thus rendering a hard, impermeable layer on the outside. This layer prevents the loss of the soluble matter from the meat. After the meat has remained in the boiling water for a few minutes, the temperature may be lowered to the coagulating point of proteins and maintained until the latter throughout the meat is coagulated.

In the process of *roasting* the heat is transferred by radiation to the meat. Here again the high temperature is objectionable unless used for a few minutes at first to "seal up" the meat as in hot water. After this, a low temperature is desirable. When meat is roasted properly it retains all its original flavor and at the same time other sapid high flavored substances are formed by reactions between the extractions on the surface.

BAKING is identical with roasting only the heat is in contact with the whole surface at the same time.

Meat that is properly *stewed* is perhaps "the best cooked meat" for the flavoring matters removed from the meat are generally left in the juice which is served with the meat. The temperature at which meat is stewed should not exceed 83°C.

THE COOKING OF VEGETABLE FOODS

We have learned that meats are readily digested when raw; that the cooking of meats is to render them more palatable, and that high temperatures render them more indigestible. Vegetables are rendered more digestible by heat. This will be seen when it is remembered that plants contain cellulose and starch, which are almost incapable of digestion by man, but these compounds are made available by heat and moisture, the starch grains swelling into a gelatinous mass and rupturing the cellulose.

Cellulose is softened—and even converted into sugar—by acids and heat, this being nature's method of ripening fruit. Many foods are rendered more digestible by fermentation processes where the bacteria produce acids which, in the presence of heat, soften the hard cellulose.

Cooking is necessary for rendering most vegetable foods available and where cellulose is present in large proportions the cooking should be more thorough.

The *proteins* in vegetables are affected similarly to those of meat. Now since we have seen that animal foods are rendered less digestible by heat and that vegetable foods are rendered more, we naturally wish to understand "why." This depends upon the physical properties of the "proteins" and the "carbohydrates." When the former are heated to coagulation they shrink, the fibers of the meat not being broken; while in the case of the latter expansion accompanies heat and the cellulose walls are ruptured, thereby rendering the food more easily digested.

Let it be remembered, however, that all food is a poor conductor of heat and that a rapid application of heat results in a loss of fuel and a poorly cooked article. The temperature should be kept high enough to coagulate the proteins and to convert the starch into a gelatinous condition so as to rupture the cellulose, but should be applied slowly and for a sufficient length of time to "thoroughly cook the food."

EXPERIMENTS IN CHAPTER IV

Impurities in Water

Examine the sample of water, noting color, odor, taste, and turbidity. All of these features should be absent in the case of pure water.

Organic Matter.—(1) Evaporate 100^{cc} of water to dryness over water bath and note color and appearance of residue. Dark color indicates organic matter, which on burning gives off nitrogenous odor as burning feathers.

(2) To a sample of water in long test tube add 1^{cc} of sulfuric acid and a few crystals of potassium permanganate: if much organic matter is present the purple color is destroyed.

Test for Ammonia.—From a retort containing about 500^{cc} of the sample distill about 50^{cc} into a Nessler jar, add 2^{cc} of Nessler solution, allow to stand a while and observe any brown coloration due to ammonia.

Test for Nitrites.—Place 100^{cc} of sample in Nessler jar, acidify with one drop of hydrochloric acid, add 2^{cc} of sulfanilic acid solution, then 2^{cc} of solution of hydrochlorid of naphthylamine. Mix thoroughly and set aside for at least thirty minutes. A pink color indicates nitrites.

Test for Nitrates.—Add to 10^{cc} of sample an equal volume of concentrated sulfuric acid, cool, and add *cautiously*—without mixing—ferrous sulfate. A brown ring at the junction of the two liquids indicates the presence of nitrates.

Alkalinity.—To 100^{cc} of water in a beaker add a few drops of "methyl orange" as an indicator. Note the orange color due to alkali. Add one drop of hydrochloric acid, stir, and note pink color due to acid.

MINERAL MATTER IN WATER

The most common salts found in water are the following: Calcium, sodium, potassium, magnseuim, iron, aluminium, and lithium, combined as chlorids, carbonates, sulfates, silicates, and sometimes as borates and arsenates.

Test for Calcium.—To 10^{cc} of water add few drops of ammonium chlorid, few drops of ammonium hydroxid, then ammonium oxalate. White precipitate of calcium oxalate indicates calcium. (Save to test for Mg.)

Test for Magnesium.—Filter off the calcium oxalate and add hydrogen-sodium-phosphate. Shake *well.* Any white crystalline precipitate of ammonium-magnesium-phosphate indicates the presence of magnesium.

Test for Iron.—To 5^{cc} of water add ammonium hydroxid in excess. Brown precipitate or color indicates iron. To each of two samples add:

(a) Potassium-ferro-cyanid $[K_4Fe(CN)_6]$, a blue color indicates ferric iron.

(b) Potassium-firri-cyanid $[K_3Fe(CN)_6]$, a blue color indicates ferrous iron.

Also ammonium-sulfo-cyanid produces a blood red color with ferric—but no color with ferrous—salts.

Test for Lead.—To a sample of water acidified with hydrochloric acid add a few drops of hydrogen-sulfid. Black or brownish color indicates lead.

It is dangerous to use water from lead pipes, for all soluble lead salts are poisonous. Test the solubility of lead in pure water by placing lead in a beaker of water for an hour, then test water for lead.

Test for Sulfates.—To a sample of water acidified with hydrochloric acid add a few drops of barium chlorid. A white precipitate of barium sulfate indicates sulfates.

Test for Chlorids.—To sample of water add a few drops of nitric acid, then silver nitrate. A white precipitate of silver chlorid indicates chlorids.

Test for Carbonates.—Evaporate 200^{cc} to dryness and add few drops of hydrochloric acid to residue. Effervescence due to liberation of carbon dioxid proves the presence of carbonates. (Save this residue to test for potassium and sodium with.)

Test for Potassium.—A platinum wire dipped in the solution left from test for carbonates and held in a non-luminous burner flame will produce a violet flame.

Test for Sodium.—Same as above except sodium produces a yellow flame. (Where these two elements occur together a spectroscope is necessary to get best results.)

Test for Sulfur.—If a soluble sulfid is present a silver coin will be blackened when dipped into the solution.

HARD WATERS

When water contains the acid carbonate of either calcium or magnesium it is said to be *temporarily hard.* Water is *permanently hard* when it contains the chlorids or sulfates of calcium, magnesium, iron, or aluminium. Temporary hardness may be removed by boiling the water, the following reaction of the acid salt taking place: $CaH_2(CO_3)_2+heat=CaCO_3+CO_2+H_2O$. The addition of lime water will often soften the water as follows: $CaH_2(CO_3)_2+Ca(OH)_2=2CaCO_3+2H_2O$.

Permanent hardness can not be removed by any simple means.

TEST FOR HARDNESS

Hard waters cause much loss of soap for the reason that the metals of the water form insoluble soaps by replacing the sodium or potassium of the original. A soap never produces a permanent lather until all these compounds of the water have been united with. Remembering this principle we can determine the "hardness" of water as follows:

Place 100^{cc} of the water in a flask and allow a standard soap solution (made by dissolving 10 grams of castile soap in one liter of alcohol diluted with one-third water) to run in about one-half cubic centimeter at a time from a burette (shake well after each addition) until a lather is produced which persists for five minutes. Record the number of cubic centimeters of soap solution required and compare with the number required to produce a lather in distilled water.

PER CENT. OF WATER IN FLOUR

Weigh out one gram of flour and place in weighed porcelain crucible. Heat in oven at 120°C. for one hour, cool in desiccator and weigh.

To find per cent. 1:loss of weight::100:X.

EXPERIMENTS IN CHAPTER V

Examination of Mineral Matter

Dissolve the mineral matter from a bone by allowing the latter to stand for a few days in dilute hydrochloric acid. The rigidity of the bone will be removed, but the nitrogenous substance *ossein* will retain the original shape of the bone. Evaporate a portion of the acid solution to dryness and note the mineral residue.

Test some of the solution for calcium, iron, magnesium, potassium and sodium as in tests for these metals in water.

Test some of the solution for phosphorus by adding ammonium molybdate.

Bone is composed chiefly of calcium phosphate.

Burn any article of food in a porcelain crucible and note the mineral matter left.

Determine the per cent. of mineral matter in flour: Weigh out one gram of flour and char over a low flame at first, but increase the heat until all the organic matter has been driven off. Cool in desiccator and weigh. Calculate per cent. as follows: 1 :weight of ash : :100:X.

EXPERIMENTS IN CHAPTER VI

Carbohydrates

Tests with Starch—

A.—Test the solubility of starch in cold water by adding a drop of iodine solution to the cold water containing starch.

Starch in solution gives a blue color with free iodine. Did the cold water dissolve the starch or not?

B.—Bring another part of water containing starch nearly to boiling, cool, and add a drop of iodine solution.

Recall the changes taking place when starch is heated and apply to your conclusions.

Boil some of the blue solution and note the result.

C.—Test grains of cereals, etc., for starch.

D.—Starch when heated gently up to about 150°C is converted into dextrin. Treat a sample of dry starch in this manner and note the changes in taste and appearance.

E.—Burn a small sample of starch in a test tube and note the character of the residue.

The pungent odor is due to hydrocarbons given off. Caramel will condense in the cool part of the tube.

Also treat a small sample with concentrated sulfuric acid and note the character of the residue. Do these tests suggest the components of starch?

F. Convert a dilute starch paste into a solution of glucose and maltose by digesting it with dilute sulfuric acid for a few minutes. Test part of the solution with iodin to see if all the starch has been converted into glucose. Save part of the solution to test for glucose with Fehling's solution.

SUGARS

By hydrolysis, cane-sugar—$C_{12}H_{22}O_{11}$—is converted into the invert sugars dextrose and levulose, each having the formula $C_6H_{12}O_6$.

A.—Note any difference between the cane-sugar or sucrose and grape-sugar or glucose. Note solubility, effect of heat, effect of concentrated acids, etc.

B.—Mix some of each sugar solution with yeast, place in fermentation tubes, set away in a warm place for a day and note any evolution of carbon dioxid gas. Explain the change.

Any reducing sugar as glucose will produce a red precipitate of copper oxid when boiled with Fehling's solution.*

C.—Test glucose with Fehling's solution.

Test sucrose with Fehling's solution.

D.—Any dilute mineral acid will convert cane-sugar into dextrose and levulose. This may be shown by digesting at about the boiling point a solution of cane sugar and dilute sulfuric acid, and testing the solution with Fehling's solution—remembering that cane sugar does not reduce the solution.

E.—Starch, when boiled with a dilute mineral acid, will reduce Fehling's solution, showing that some of the reducing sugars have been produced.

Starch undergoes hydrolysis when in contact with saliva, pancreatic juice, and several other ferments of the body. This may be shown as follows:

A.—Add to a thin starch paste some saliva, mix well and keep in a warm place for about fifteen minutes; then test with Fehling's solution.

B.—Pancreatin, when dissolved in water and mixed with starch, converts the latter into glucose and maltose. The absence of starch in a paste that has been treated with pancreatin for a day—the mixture being kept at about 98°F.—may be shown by the starch test, while the presence of the invert sugars may be shown by the Fehling test.

CELLULOSE

Cellulose is classified, by some authorities, as a carbohydrate, so we shall make a few tests to show its insolubility in common solvents, etc.

A.—Test its solubility in water, dilute, acids, alkalis, etc. (Use cotton, a piece of filter paper, or some other article which is nearly pure cellulose.)

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*Fehling's solution is made by dissolving 34.6 grams of crystallized copper sulfate in water and diluting it to 500^{cc}.

Dissolve 175 grams of Rochelle salts and 50 grams of sodium hydroxid in water and dilute to 500^{cc}.

Mix the two solutions just before using them.

Then try its solubility in concentrated acids, etc.

B.—Cellulose is soluble in copper hydroxid, or zinc chlorid.

C.—Test with iodin for blue color.

D.—Test with Fehling's solution.

EXPERIMENTS IN CHAPTER VII

Fats

A true fat is a glycerid of fatty acid and contains carbon, hydrogen, and oxygen.

There are some hydro-carbons which closely resemble fats, but which are not true fats.

There is only the physical difference of "solid" or "liquid" that separates oils and fats.

To show the presence of water in fats, boil in a dry test tube a little of the fat and note the condensation of water on the cold neck of the tube. Note the cracking sound when this water runs back into the oil.

Acrolein is given off as dense fumes if the heating is carried to a sufficiently high temperature. Acrolein is a decomposition product of glycerine: $C_3H_5(OH)_3=C_3H_4O+2H_2O$.

Carbon and Hydrogen in Fats.—Pour the solution used in above experiment into a porcelain dish and heat strongly over a low flame. Note the darkening of the liquid due to separation of carbon. Test the inflammable character of the gases given off—hydrocarbons.

Fat and oils are insoluble in hot or cold water, but are soluble in chloroform, gasoline, ether, and hot alcohol.

Extraction of Fats.—Weigh out 1.5 grams of any food—flour, for instance—and place it in the extraction apparatus. Allow the ether to percolate through the material for twenty-four hours. Evaporate the ether and note the oil left. Weigh the oil in the bottle—that has been weighed empty—and calculate the per cent. of fat in the sample.

A.—Test the *solubility* of a small piece of fat in water, then in alcohol and note results. Heat both test tubes and note results.

B. *Acidity.*—Dissolve a small piece of fat in a clean dry test tube with neutral alcohol by heating. Cool and test with a small piece of litmus paper.

C.—Place a fatty compound—or fat—on a piece of dry filter paper and heat slowly, noting the *oily spot produced on the paper.*

D.—(1) *Emulsification.*—Shake a few cubic centimeters of a fat or oil with twice its volume of dilute caustic soda solution and note appearance.

(2) Treat an equal volume of the oil with water, allow to stand a while and note the difference between the two solutions.

E. *Effect of Acids and Alkalis on Fats.*—Pour a little oil into a dilute acid solution in one test tube and an equal volume into a second test tube of an alkali. Shake the two, then allow to stand a while and note any difference in the two solutions.

Can you suggest a reason why fats are not digested in the stomach and why an acid is never used to remove a grease spot?

F. *Saponification of Fats.*—Boil a mixture of some oil or fat with sodium hydroxid, cool and note the soap produced. If all the fat has not been saponified add more of the alkali and boil. (The process of soap-making will be taken up in a later chapter.)

TESTS IN CHAPTER VIII

Proteins

Proteins contain carbon, hydrogen, oxygen, and often sulfur, phosphorus, and a little iron.

The following simple tests will determine the qualitative character of the proteins:

1. *Determination of Nitrogen as Ammonia.*—Mix some of the protein body—e. g., egg albumen—with lime, roll into little balls, and place one or two of these in a test tube and heat gently, holding a moist piece of red litmus paper near the neck of the tube. Ammonia may be recognized by its odor and by the blue color produced on the paper.

2. *Detection of Sulfur as Hydrogen Sulfid.*—Hold a piece of filter paper that has been soaked in lead acetate solution in the fumes of Exp. 1. Hydrogen sulfid manifests its presence by producing a black precipitate of lead sulfid on the paper.

3. *Detection of Hydrogen and Oxygen as Water.*—Note the condensation of water in the cool part of the tube in the above experiments.

4. *Detection of Carbon.*—Note the black residue produced by the freeing of carbon.

5. *Phosphorus* may be detected by oxidizing the residue from the above experiments with nitric acid and heat. Cool the residue when clear, add water *carefully*, then add ammonium molybdate solution and keep at a temperature of 65°C. for a while. A yellow precipitate indicates phosphorus.

The following are *General Properties* of nitrogenous compounds:

1. *Solubility.*—Any protein is soluble in a dilute solution of sodium chlorid; but only albumens and gelatin in warm water.

2. *Coagulation.*—Albumens are coagulated by heating to a temperature of 70°C. and by the addition of a dilute mineral acid.

For some of the general tests on proteins an egg albumen solution made as follows is recommended: Shake the macerated white of a fresh egg with about ten times its volume of distilled water. Invert over a beaker of distilled water and when the froth has risen to the top let part of the clear solution run into the beaker. Shake well—if not clear, filter through cloth, and if alkaline, neutralize with dilute acetic acid.

General Tests.—1. *Nitric acid*, if concentrated, will produce a white precipitate which turns yellow on heating. If this solution is cooled and ammonia added it will turn orange. Nitric acid spots on woolen clothing and on the skin resemble this color.

2. *Biuret Test.*—To a dilute caustic potash solution add cautiously dilute copper sulfate until a faint blue *color* remains after shaking. To this add the solution of protein: a violet color indicates protein, while a pink color is characteristic of peptone.

3. Proteins in solution are *precipitated* by either alcohol, picric acid, or tannic acid.

4. *Coagulation by Heat.*—Boil some of the egg solution and note any change. If the albumen is not coagulated, add dilute acetic acid and heat.

The following are special tests for Albumen and Globulins:

1. *Millon's Test.*—Millon's reagent produces with albumen solutions, when heated, a white precipitate which is red when cold; however, a red color is obtained when the protein is present only as a trace.

2. *Heller's Test.*—When concentrated nitric acid is placed in a test tube and an albumen solution poured cautiously down the side of the tube a white ring of precipitated albumen is formed where the liquids touch.

3. The following reagents precipitate albumens from solution; Lead acetate, mercuric chlorid, acetic acid and potassium ferrocyanid.

Other Precipitation Tests.—Dry sodium chlorid will precipitate globulin from the egg solution, while dry ammonium sulfate will precipitate both albumen and globulin.

Conversion of Egg Albumen Into Peptone.—Place three small pieces of coagulated egg albumen in three test tubes. To the first add a *very dilute* solution of hydrochloric acid.

To the second add a dilute neutral solution of pepsin.

To the third add both hydrochloric acid and pepsin.

Place the three tubes in the oven and keep at 98°F. until they are clear. Which cleared up first? Then filter and test the three filtrates for peptones by the Biuret test.

Ther are many other protein bodies. A few common ones are:

A. *Gluten*, which is the elastic part of flour. Gluten is left when the starch, etc., are washed away from flour.

B. *Casein*, which is the nitrogenous substance which separates from milk when heated—especially in the presence of a little acid.

C. *Myosin*, which is found in muscles.

GELATINOIDS

Gelatin is made by boiling bones, tendons, ligaments, connective tissue, etc., with water and allowing the solution to cool. Try this and test the cold solutions for gelatin with either dilute hydrochloric acid, picric acid, acetic acid, salt and tannin, lead acetate, Heller's test, or the biuret test.

Keratin is an insoluble, resistant substance, which is found in hair, skin, nail, and horn.

Test one of these substances for nitrogen and sulfur.

Mucin is found in saliva and may be precipitated out with acetic acid.

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